A FINITE-ELEMENT MODEL OF MULTI-RING BASIN RIDGE SYSTEMS. Ted A. Maxwell, National Air and Space Museum, Smithsonian Institution, Washington, D. C. 20560

Lunar mare ridge systems have been studied at scales ranging from local (1,2,3) to regional (4), and their origin has been postulated to be purely volcanic (5), purely structural (1,6), or combinations of the two. Although the resulting maps and geologic relationships provide strong constraints for the origin of these features, the details of their formation are still subject to debate. For reasons previously enumerated (1,7), a structural origin is herein preferred for the major circular ridge system within the Serenitatis basin. Using this basin as an example, the present study is an attempt to simulate ridge formation and basin deformation by purely structural means.

The inner-ring ridge system of Serenitatis is approximately 400 km in diameter, and is formed completely within the younger basalt of central Serenitatis. On the basis of spectral imaging (8) and orbital chemistry (9), there is no major difference in chemistry between the ridge system and surrounding mare, which supports a structural origin. Previous studies have shown that between 0.5 (6) and 0.8% (7) of cross-sectional shortening could cause the uplift that is represented by the major ridge system. As pointed out by Muehlberger (6), however, one major problem that remains is explaining the fact that measured shortening is greater than that calculated from subsidence alone. This discrepancy was used as evidence that a global stress system has been necessary for the formation of ridge systems. The present study, therefore, has been undertaken to answer the following questions: 1) Can a ridge system form purely as the result of horizontal stresses created by subsidence of a basalt layer (10)? 2) Is a global stress system necessary? and 3) How valid is an elastic model of subsidence?

The finite-element method has recently been applied to a variety of structural geologic problems ranging from simulation of ground-motion during a volcanic eruption (11) to determination of *in situ* stress orientations in a mine (12). Essentially, the method consists of generating a two-dimensional model composed of triangular elements, applying a directional stress to a portion of the model, and allowing the elements to deform according to predetermined elastic constants. The program used (ASAPS; courtesy of J. Dieterich) will rotate the finite-element mesh axisymmetrically, and thus allow for three-dimensional deformation.

Consequently, the model is treating only *elastic* deformation. In reality, however, near-surface faulting, and creep at depth may be more valid modes of deformation. For the sake of simplicity, however, the present model is concerned only with elastic response to applied stress.

An axisymmetric "basin" composed of 308 elements (Fig. 1) was used to simulate the central part of a 500 km (diameter) circular basin flooded with 10 km of basalt. This amount of basalt overestimates that determined from photogeologic studies and gravity models, however, it was found necessary in order to compensate for the relatively high strength assigned to near-surface material. For this model, stresses were assumed to be gravitationally induced by flooding of the basin with basalt, and were applied at the base of the mare

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basalt layer. A computer program was written to integrate these stresses axisymmetrically in order to provide the y-components of force for each node of the initially stressed element (triangle).

The geometry of the model can be estimated from geologic mapping, comparisons with the Orientale basin, and a limited amount of subsurface information (13). Similarly, constraints on the elastic parameters of lunar rocks can be drawn from studies of the physical properties of returned samples (14,15). Although the presence of microcracks may significantly alter these values, the constants derived from the formulae of isotropic elasticity (16) should be accurate for regions deeper than about 25 km (17). Highlands surrounding and beneath the basin were assigned Lame elastic parameters of $\lambda = 0.15$ and $\mu = 0.12$; and for the basalt layer, $\lambda = 0.12$ and $\mu = 0.11$.

As shown in Fig. 2, pure elastic deformation can account for only a small fraction of deformation seen in the Crisium or Serenitatis basins. For the 10 km thick layer of basalt (assumed $\rho = 3.0$), the downdropping at the center of the basin was 65 m. A more realistic estimate of about half that thickness would therefore result in even less subsidence. The great discrepancy between actual amount of downdropping and that resulting from the model is most likely the result of the fact that the simulation did not take into account either long term creep, faulting at the basin margin, or the relative weakness of the uppermost basalt layers. Present models are being investigated which have much weaker near-surface layers, and initial normal forces distributed throughout the basalt layer.

Although this simulation did not account for the absolute magnitude of basin subsidence, there are three preliminary conclusions. 1) In the shelf region of the model, a maximum of 15 m of extension (towards the basin center) has occurred. This extension is represented in the Serenitatis basin by the Plinius and Littrow arcuate rille systems. 2) The change in horizontal displacement from positive (outwards) to negative in the upper surface of the model may be used as an indication of where a compressional ridge system would be located. The change in sign of horizontal displacement occurs between 0.52 and 0.68 times the basin radius. 3) Although the strength of the upper layer was so great that very little vertical displacement actually took place, it is interesting to note that the subsidence was slightly less ($\simeq$ 1 m) at the basin center than at the margin. Consequently, present results indicate that a pure elastic model of basin subsidence does not account for the magnitude of strain recorded on the lunar surface, although the location of deformation lends some credence to the model. Either a global stress system (6) or basement involvement (13) most likely aided formation of the major ridge systems.

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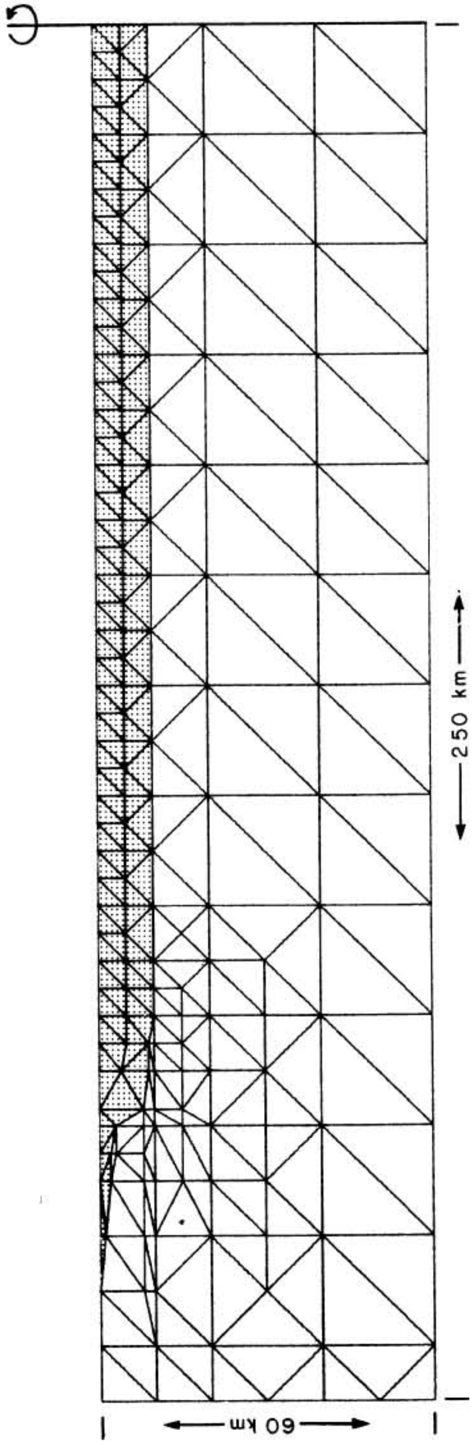

FIGURE 1. Axisymmetric finite-element model of a 250 km radius lunar basin flooded with 10 km of basalt (patterned).

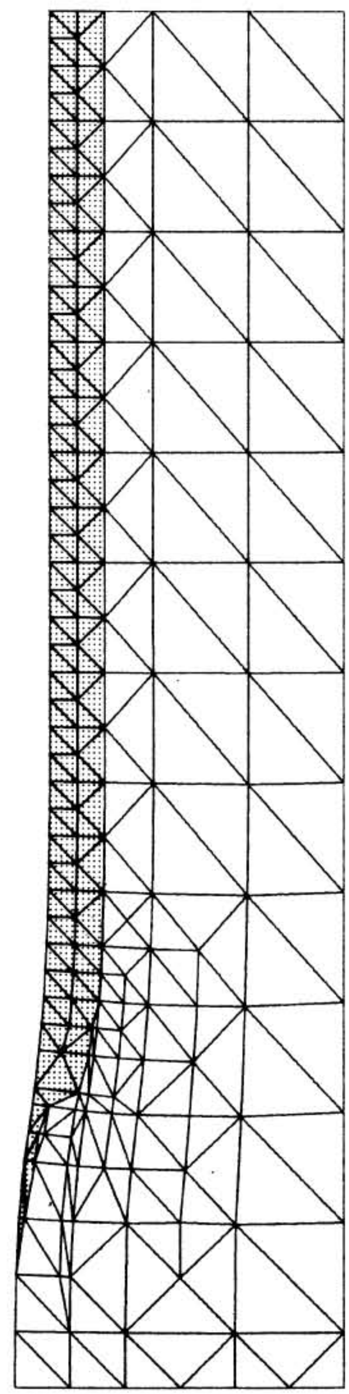

FIGURE 2. Lunar basin model after deformation. Note extension of surface over shelf region. Both x- and y-components of displacement are exaggerated 100 X.